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Past, present and future of the luminous variable Romano's Star in M33

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Abstract. Analysing archival data and new spectroscopic and photometric observations we find that the luminous variable Romano's Star in the M33 galaxy (GR 290) has an historical light history somehow resembling that of classical Luminous Blue Variables (LBV), but is displaying a much hotter spectrum typical of late WN stars. From model analysis and comparison with evolutionary tracks for massive stars, we find that the star has evolved from 60 M_0 star and presently its place in the H-R diagram is close to that of WN8h stars. We argue that GR 290 has just left the LBV state and is moving towards the WN stars. A crucial aspect of this star is the significant increase of its absolute luminosity at the light maxima.

Key words. Stars: emission-line; Stars: variables; Stars: individual, GR290

1. Introduction

The variable star no. 290 of Romano (1978a), hereafter GR 290 (also named M33/V532), is a hot luminous star in the Triangulum Galaxy (M33). The star is located near two young OB clusters at about 4 kpc from the galaxy centre. Romano (1978b), on the basis of the large luminosity variations of the star, first identified GR 290 as a Hubble-Sandage variable. Later the star was suggested by several authors to be a Luminous Blue Variable (LBV). But recently, Polcaro et al. (2011) argued that, because of its extreme spectrum at the 2008 visual minimum (WN8h), GR 290 is not too far from the end of the LBV phase and, probably, it is already evolving toward a late-WN-type star. To shed light on the matter, we have investigated the past and present behaviour of GR 290 in order to determine its physical structure and evolutionary state, and to find out its destiny.

2. The light curve history of GR 290

We have found GR 290 on previously unexplored plates of Hamburg, Pulkovo, Heidelberg, Palomar and Asiago plate archives. Combining these data with new photometric observations (Polcaro et al. 2015) and with data published by (Romano 1978b;

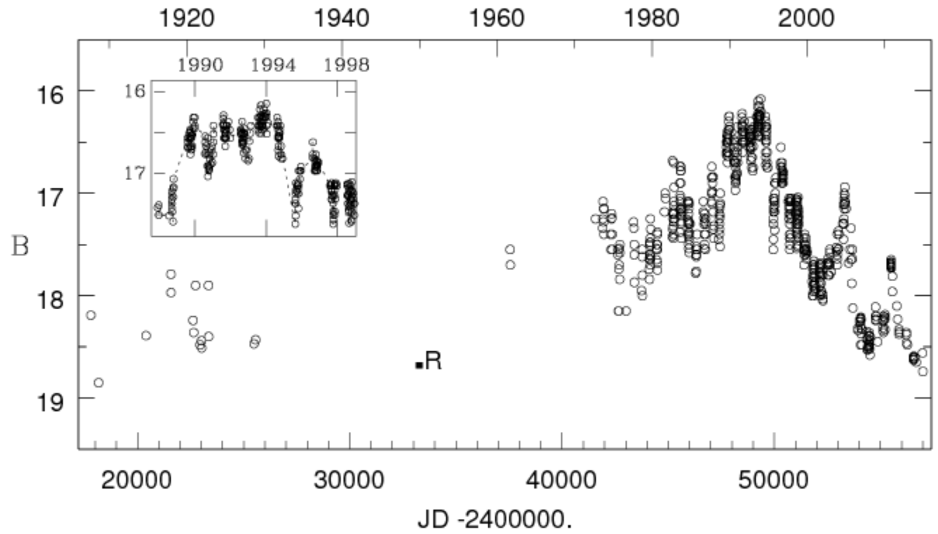

Fig. 1. The historical B light curve of GR 290 from 1907 to date. The R POSS magnitude is also shown.

Polcaro et al. 2011; Sholukhova et al. 2011) we draw the light curve from 1907 to date (Fig. 1). During the last one hundred years the light curve of GR 290 was characterized by two main phases: (1) a long period of quasi-quiescence at B=18-19m (recalling the long lasting minimum phase of many LBVs). (2) Since 1960 the star underwent at least five large luminosity maxima (S Doradus-type cycles) separated by 7 to 10 years. As seen in the figure, there was a gradual increase of the luminosity peak of the first maxima up to the main maximum of 1992-94 (which somehow resembles the giant outbursts of LBVs), followed by a gradual decrease of the light peaks.

3. Spectral variations

The last cycles were characterised by large spectral variations markedly anti-correlated with luminosity, being the equivalent spectral type WN10-11h near maximum and WN8-9h near minimum. This is also illustrated in the spectra shown in Fig. 2 and by the temporal evolution of the temperature dependent ratio of the equivalent widths of the HeII 4686 Å and HeI 5876 Å emission lines (Fig. 3).

4. Physical parameters of GR 290

The low resolution spectra and the photometric measurements of GR 290 during 2002-2014 were analysed with the CMFGEN code model atmospheres (Polcaro et al. 2015; Maryeva & Abolmasov 2012), which allowed to derive the range of variability of the main stellar parameters during the last S Doradus cycles: log (T_{eff})=4.37-4.52, logL/L⊙=5.7-6.0, mass loss rate =1.4-4x10-5 M⊙/yr, and N(He)/N(H)~1.7. From comparison with evolutionary tracks of massive stars (Chieffi & Limongi 2013) we find that the stellar luminosity and temperature suggest that the star has evolved from an initial mass around 60 M⊙ and has an age of about 4 million years (Fig. 4).

5. The variable absolute luminosity of GR 290

From the model analysis we have found that the stellar absolute luminosity at the light maxima is a factor 1.5 higher than at the light

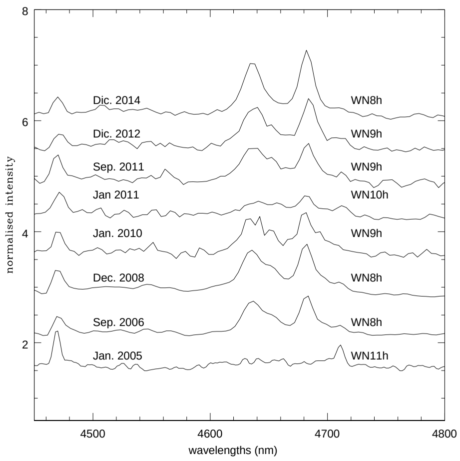

Fig. 2. Variation of the spectra in the last 10 years

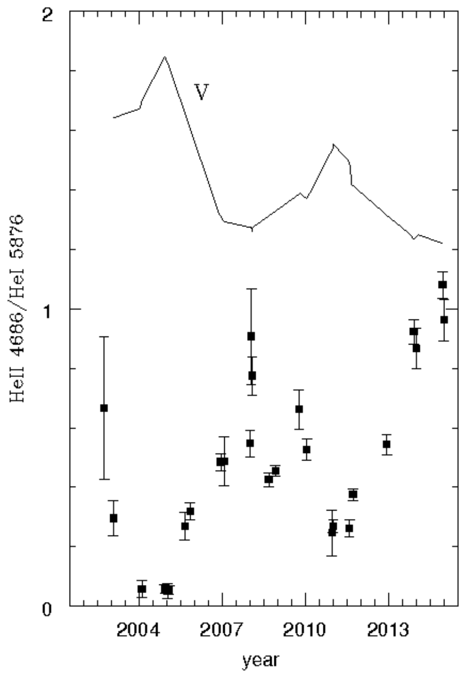

Fig. 3. Variation of the temperature dependent HeII4868/HeI 5876 equivalent width ratio compared with the visual light curve (from Polcaro et al. 2015).

minima, the variation being in phase with the S Doradus light oscillation. The recent path of GR 290 in the H-R diagram is shown in Fig. 5: except during the 2005 light maximum the star was always far from the LBV minimum instability trip. At the last light minima its position is close to that of late WN stars in LMC (Hainich et al. 2014), and has an effective temperature of 33.000 K. However, apart from the variability, there are other important differences between GR 290 and the classical late-WN stars: the low wind velocity (~400 km s^{-1}) and the relatively high hydrogen abundance. From this point of view GR 290 could be considered as a young WN8 star. The large absolute luminosity increase during light maxima might suggest that the star has still been subject to bursts of internal origin which supply extra radiation power, as for instance suggested by Guzik & Lovekin (2012) for the LBV giant outbursts. However, GR 290 is the first (post)-LBV object for which there is a clear evidence for periodic changes of bolometric luminosity, and we cannot exclude that this fact be linked to its high stellar temperature. Indeed, this is a point that should require further theoretical investigation.

6. Conclusions

GR 290 shares some characteristics of both LBV and WN8 stars. It is (1) too hot to be in the LBV evolutionary phase of very massive stars, but (2) it has many structural differences (wind velocity, hydrogen abundance and variability) with respect to late WN stars, which suggest the star to be evolutionarily younger than them.

We argue that presently the star is gradually changing its structure, and in a relatively short time it will become a fairly stable late WN star. In this regard GR 290 should be the first massive star observed in the transition phase from LBV to WR stars of the nitrogen sequence. A full report on this research has been recently published by Polcaro et al. (2016).

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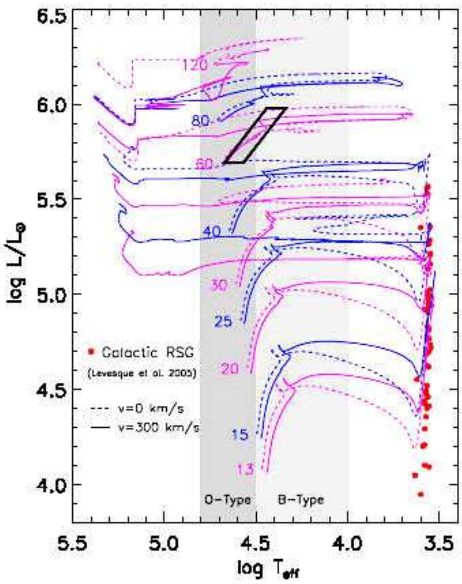

Fig. 4. The variability range of GR 290 during 2002-2014 (enclosed area) in the Temperature-Luminosity diagram superposed on the Chieffi & Limongi evolutionary tracks for models with different initial mass.

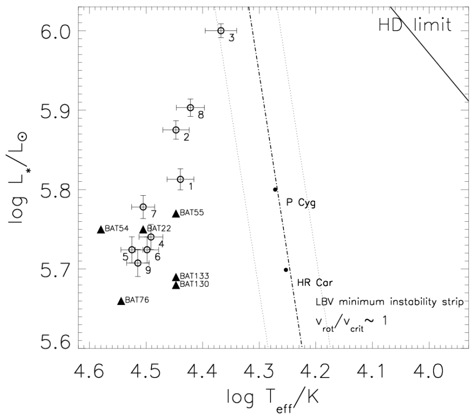

Fig. 5. The position of GR 290 from 2002 (1) to 2014 (9) in the H-R diagram. The position of some late WN stars is indicated (from Polcaro et al. 2015).

cal light curve using Asiago, Heidelberg, Hamburg, Pulkovo and Palomar plate archives. O. M. thanks the grant of Dynasty Foundation and the RFBR (projects no. 14-02-31247,14-02-00291). This work made use of the SIMBAD database.

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